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Influence of muscle-sparing lateral thoracotomy on postoperative pain and lameness: A randomized clinical trial

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Abstract

Objective: To assess and compare the magnitude of lameness and level of pain after muscle-sparing lateral thoracotomy (MSLT) and standard lateral thoracotomy (SLT) in dogs.

Study design: Randomized, blinded, prospective clinical study.

Animals: Twenty-eight client-owned dogs.

Methods: The latissimus dorsi muscle was retracted in the MSLT group and was transected in the SLT group. Gait was analyzed with a force plate, and the peak vertical force symmetry index (SI) was calculated within 24 hours before surgery, 3 days postoperatively, and 8 to 12 weeks postoperatively. Symmetry index and pain scores as measured by the Glasgow Composite Measure Pain Scale - Short Form were assessed as primary outcome measures.

Results: The SI 3 days postoperatively was lower compared with the preoperative SI value in all dogs, consistent with lameness of the ipsilateral thoracic limb ($P < .001$). The absolute differences in preoperative and 3-day-postoperative SI provided evidence that this change was 3.1-fold greater after SLT compared with after MSLT ($P = .009$). Pain scores 1 day after surgery were lower after MSLT (1) compared with after SLT (2.5, $P < .001$).

Conclusion: Lateral thoracotomies caused postoperative pain and ipsilateral forelimb lameness, and both were reduced by sparing the latissimus dorsi.

Results of this study were presented as a scientific abstract at the 28th ECVS Annual Scientific Meeting; July 4-6, 2019; Budapest; Hungary and at the 2019 ACVS Surgery Summit; October 16-19, 2019; Las Vegas, Nevada.

Clinical significance: Sparing the latissimus dorsi should be considered to decrease immediate postoperative morbidity in dogs undergoing lateral thoracotomy.

1 | INTRODUCTION

Intercostal thoracotomy remains the most widely performed surgical procedure for entering the thoracic cavity in small animals, despite the increasing development of minimally invasive procedures.[1-3] Complications associated with this procedure include dehiscence, hemorrhage, wound discharge, excessive wound inflammation, infection, pyothorax, seroma formation, and, rarely, rib fracture.[4-7] Pain can be severe after thoracotomy and cause to adverse effects such as pulmonary dysfunction (via restrictive ventilation and/or abnormal breathing pattern) and ipsilateral thoracic limb lameness.[4,8,9] Causes of pain are secondary to a combination of factors, including muscle trauma from dissection, rib retraction, neurovascular compression secondary to circumcostal rib closure, and limb overextension intraoperatively.[2,4-6] Intercostal thoracotomy can be performed by using muscle-sparing (including muscles involved in limb function) or non–muscle-sparing (standard) techniques. In man, muscle-sparing thoracotomies are commonly performed, and claimed advantages include less acute and chronic pain, improved pulmonary and shoulder function, and fewer wound complications.[10,11] In contrast, the literature on the subject in animals is sparse; the authors of one study described the technique of muscle-sparing lateral thoracotomy (MSLT) in 20 dogs,[12] and those of a second study compared postoperative pain between the two techniques, concluding that muscle-sparing lateral thoracotomy was less painful than standard lateral thoracotomy (SLT).[13] However, pain scoring was not performed with a validated method, and the observer was not blinded. In a third study in which factors associated with outcome after thoracic surgery were investigated, 16 of 77 dogs undergoing intercostal thoracotomy underwent MSLT.[3] Better ambulation was reported postoperatively with MSLT compared with SLT, but this was not measured objectively.

The primary objective of the study reported here was to compare objectively the degree of lameness and pain after MSLT and SLT in a randomized, blinded, prospective clinical study. We hypothesized that the MSLT technique would result in lower levels of postoperative pain and reduced lameness compared with the SLT technique. Our secondary objective was to determine whether there were differences in performing an MSLT in terms of surgical time, incision length, hemorrhage, and wound inflammation.

2 | MATERIALS AND METHODS

Ethical approval was given by the University of Bristol, Animal Welfare and Ethical Review Body (VIN 15/044). Dogs were enrolled with informed owner consent, which ensured understanding of the random inclusion of their dog into one of the two treatment groups and use of gait analysis preoperatively and postoperatively. Dogs weighing >10 kg and requiring fourth or fifth intercostal space thoracotomies for any surgical procedure were enrolled in the study. Dogs were required to be well enough to undergo moderate exercise to enable acquisition of force plate data. Those unable to do so because of their thoracic disease or any other cause were excluded from the study. However, dogs were included when they were deemed well enough to exercise after thoracocentesis via needle or thoracostomy tube placement (MILA International, Florence, Kentucky). All dogs underwent orthopedic examination prior to inclusion, and those with visible lameness were excluded. Dogs with suspected osteoarthritis based on mild reduced range of joint movement and/or mild joint pain were included when no lameness was visible. Selected cases were allocated randomly into two study groups by using permuted block randomization, and the study group was revealed to the surgeon only at the time of surgery. A set of detailed instructions was presented and then given in a written document to the surgical team including details on the surgical approach, the difference between MSLT and SLT and the variables to record. The main study investigators (A.E.N, G.C.) were present during the first surgeries to ensure good adherence to the study protocol until the entire surgery team became confident with the study steps. Surgeries were performed by board-certified surgeons or by a resident under their direct supervision. In the MSLT group, the latissimus dorsi was preserved by retraction rather than by resection, and the serratus ventralis, scalenus, and external abdominal oblique muscles were separated and retracted when possible. In the SLT group, these muscles were transected to expose the correct intercostal space. When a dog required a second thoracotomy on the same side, the dog was still included as long as disturbance of the latissimus dorsi muscle at the second site was not required (ie, the intercostal space [ICS] to be entered was caudal enough that the muscle did not require transection or retraction). In the absence of any prior force plate data, we were unable to carry out a sample size calculation, but we anticipated enrolling at least 10 animals in each arm of the study on the basis of previous published studies in which pain level was used as an outcome measure.[13]

2.1 | Muscle-sparing lateral thoracotomy surgical approach

By following a standard approach through the superficial structures by using a scalpel or diathermy, the ICS was located, and the overlying latissimus dorsi muscle was freed from its attachments to the chest wall by sharp and blunt dissection at the ventral border by using Metzenbaum scissors. Digital dissection was continued cranially, caudally, and dorsally to allow exposure of the ICS when the latissimus dorsi was retracted dorsally with a Langenbeck retractor. The serratus ventralis, scalenus, and external abdominal oblique muscles were also "spared" by undermining, separation, and retraction. However, partial incision of the external abdominal oblique and scalenus muscles (at the tendinous junction) was allowed when it was required. The intercostal muscles and pleura were then incised. A Finochietto retractor was placed for rib retraction, and the spared muscles were either retracted by continued use of the Langenbeck retractor, or a stay suture was placed to maintain elevation (Figure 1).

2.2 | Standard lateral thoracotomy surgical approach

The approach for the SLT was the same as that for MSLT except that the latissimus dorsi muscle was partially incised over the ICS from its ventral border dorsally to the proximal third of the thorax to allow access to the underlying muscles. The scalenus was detached from the rib at the tendinous insertion, and the serratus ventralis, external abdominal oblique, and intercostal muscles were transected as required to access the pleural cavity.

2.3 | Thoracic closure

A 12- or 14-gauge thoracostomy tube (MILA) was placed through the seventh, eighth, or ninth intercostal space and guided to the cranioventral thorax through the thoracotomy incision. Incision closure was standardized by using polydioxanone (PDS; Ethicon, Somerville, New Jersey) for closure of the thoracotomy site with circumcostal sutures and for apposition of muscles. Poliglecaprone 25 (Monocryl; Ethicon) was used for closure of subcutaneous and intradermal tissue, or skin sutures were placed by using monofilament nylon (Monosof; Ethicon) in a continuous or interrupted pattern in replacement of the

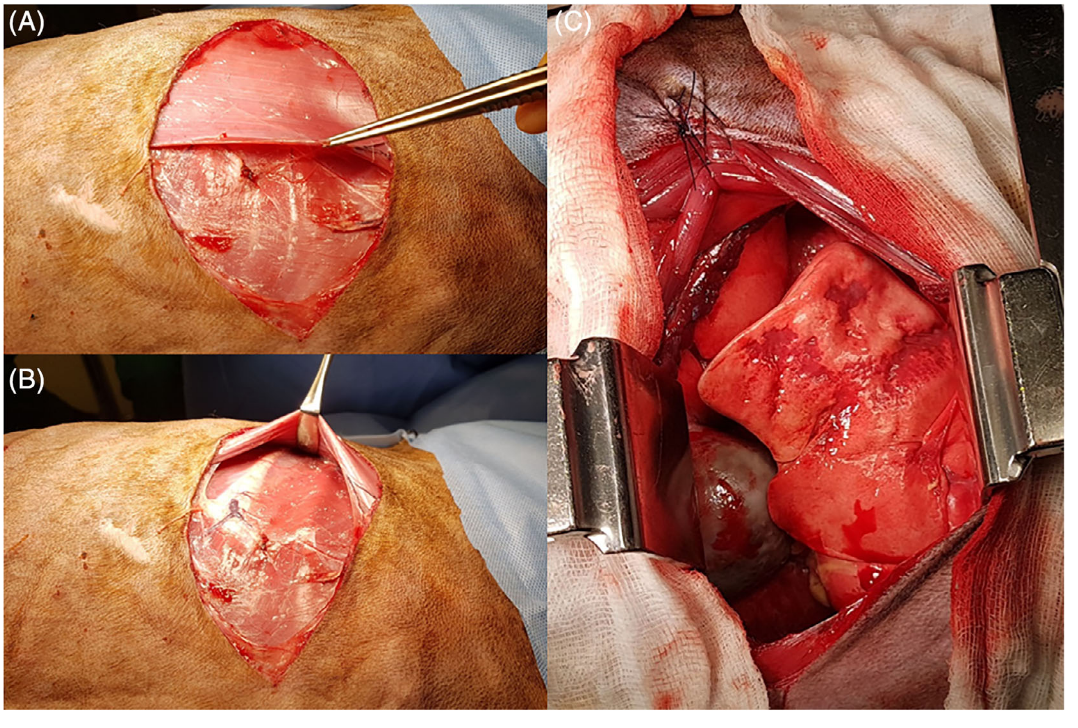

FIGURE 1 Muscle-sparing lateral thoracotomy technique. A, The ventral border of the latissimus dorsi is undermined. B, The latissimus dorsi is elevated by using a Langenbeck retractor. C, The latissimus dorsi and a section of the serratus ventralis are elevated by using stay sutures

intradermal layer at the discretion of the surgeon. No glue or staples were used. Suture size was chosen according to the dog's size.

2.4 | Anesthesia and analgesia

All dogs received the same anesthesia protocol. Dogs were premedicated with methadone (0.3 mg/kg IV). For induction, 1 mg/kg of either alfaxalone or propofol was given slowly IV, followed by 0.3 mg/kg midazolam IV. Additional alfaxalone or propofol was then given slowly to effect, typically to approximately 3 to 4 mg/kg in total. Dogs were then intubated and maintained with sevoflurane and a fentanyl constant rate infusion (CRI) at 5 μg/kg/hour. An epidural was administered prior to clipping. A 0.2-mg/kg morphine (10 mg/mL solution) total dose was calculated, which was then diluted with NaCl 0.9% until a total volume of 1 mL/4.5 kg bodyweight was reached. A local intercostal block including two intercostal nerves on either side of the incision was performed with bupivacaine (1 mg/kg) prior to thoracotomy closure. After evacuation of air and fluid from the thoracic cavity, intrapleural bupivacaine (1 mg/kg) was injected down the thoracostomy tube. This was repeated every 8 hours until the thoracostomy tube was removed or after 3 days. Paracetamol (10 mg/kg IV) was administered every 8 hours for 3 days. A nurse blinded to the thoracotomy group pain scored each dog according to Glasgow Composite Measure Pain Scale - Short Form (GCMPS-SF) every 4 hours from extubation for 48 hours and then three times daily until discharge. When the pain score was ≥6 of 24, methadone was given (0.2 mg/kg IV), and pain was reassessed 30 minutes later. This was repeated once when required, and, when the pain score still reached the threshold for rescue, the analgesic plan was tailored to the individual and recorded. After day 3, paracetamol (10 mg/kg up to every 8 hours orally) was continued if the threshold for rescue analgesia was reached.

2.5 | Outcome measures

Primary outcome measures were preoperative and postoperative peak vertical force (PVF) symmetry indices (SI) and preoperative and postoperative pain scores. Secondary outcome measures were also recorded, which included estimated blood loss during approach, duration of surgical approach, incision length, duration of surgical closure, and postoperative surgical site inflammation. Except for the latter, each was recorded as a percentage of bodyweight.

2.6 | Primary outcome measures

2.6.1 | Gait analysis

Computer-assisted force platform gait analysis was performed by using a biomechanical platform (ATMI Accugait portable force platform; Advanced Mechanical Technology, Watertown, Michigan) embedded in a 10-m walkway. Three sets of motion capture cameras (Pro Reflex 500; Qualisys, Gothenburg, Sweden) were positioned around the walkway, each approximately 2 m apart, with the middle cameras positioned on each side of the force plate. Five 12.5-mm reflective markers (Qualisys super-spherical markers; Qualisys) were attached to the dog with double-sided adhesive tape (Mammoth Powerful Grip Tape; Everbuild Building Products, Leeds, United Kingdom). One marker was placed on each axial surface of digits II and V of each forelimb, and one marker was placed between the scapulae on the midline (Figure 2). The markers were detected by the motion capture cameras, and data were used to determine velocity and acceleration (midline marker) and allow replay (digit markers) for selection of valid trials. Gait analysis was performed at the trot within a velocity range of 0.7 m/second and acceleration range of ±0.5 m/second^2. Both time series vertical ground reaction forces and kinematic data were captured from the force plate and camera systems in

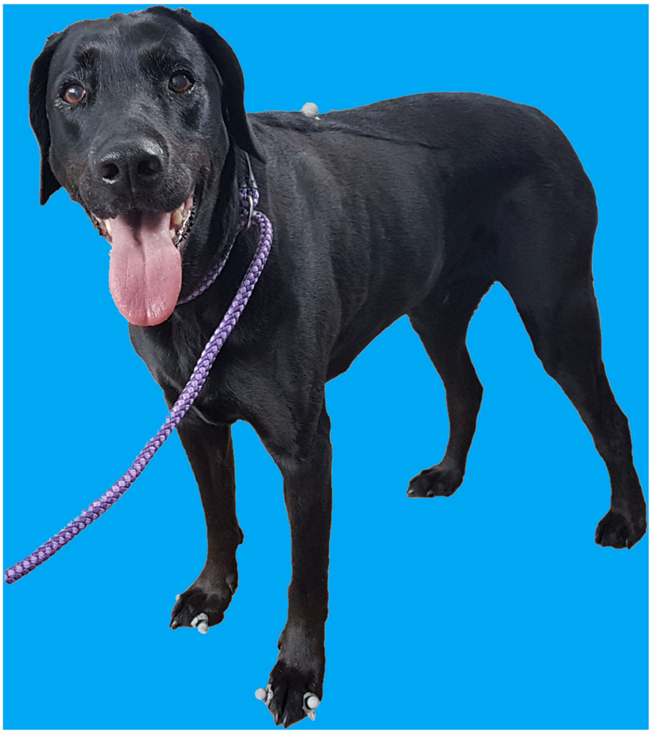

FIGURE 2 Positioning of the reflective markers for gait analysis, with two on each foot and one on the dorsal midline

Qualysis Track Manager (Qualisys) and processed in a bespoke script (Python 3.4; Python Software Foundation) to extract PVF, velocity, and acceleration data. Data were recorded within 24 hours preoperatively and 3 days and 8 to 12 weeks postoperatively. Each dog was first acclimatized to the force plate and was allowed to achieve a self-selected velocity during warm-up runs. To minimize variance in force-plate data resulting from handler differences, the same handler was used during each gait analysis session. After it had been established on which side the dog would trot most consistently during the acclimatization period, the handler led the dog on the same side for data collection. A minimum of five valid trials were collected for each thoracic limb. Symmetry indices for PVF were calculated for each dog according to the formula

$$SI = 100 \times \frac{F_i - F_c}{\frac{1}{2}(F_i + F_c)}, \tag{1}$$

where SI was the symmetry index, F_i was the mean PVF of the ipsilateral limb to the side of surgery, and F_c was the mean PVF of the contralateral limb to the side of surgery. An SI of zero indicated perfect symmetry. A negative SI indicated an asymmetrical forelimb gait with less force on the ipsilateral limb to the side of surgery, and a positive SI indicated an asymmetrical forelimb gait with less force on the contralateral limb to the side of surgery.

2.6.2 | Pain measurement

For measurement of acute pain caused by the surgery, pain scores additional to those performed as part of the analgesia plan were measured by a veterinary student or a nurse blinded to the thoracotomy group by using the GCMPS-SF. These scores were used in the data analysis. Dogs were scored once within 24 hours preoperatively, twice daily starting on the morning after surgery for 3 days, and once at the 8- to 12-week follow-up. Mean pain scores were calculated for each of the 3 days after surgery. For measurement of chronic pain during the postoperative period, the owner was asked to complete a Canine Brief Pain Inventory (CBPI) questionnaire.[14] The questionnaire was completed at admission to accustom the owner to the format and to provide practice at scoring, and it was repeated by telephone at 1 and 4 weeks postdischarge and a final time at the 8- to 12-week appointment. It was ensured that the same owner completed the questionnaire at each time point. The CBPI consists of questions pertaining to the severity of the dog's pain and how the pain interferes with the dog's daily activities. The mean pain severity score and mean pain interference score were recorded for each dog at the three postoperative time points. When a question could not be answered, a mean value of those that were answered was calculated.

2.7 | Secondary outcome measures

2.7.1 | Postoperative surgical site inflammation assessment

The incision was assessed at 24, 48, and 72 hours after surgery for signs of inflammation (swelling, erythema, heat, discharge) by a veterinary student or a nurse blinded to the treatment group. Inflammation was graded (with a maximum score of 20) according to a visual analog scale, a modification of the ASEPSIS (Additional treatment, Serous discharge, Erythema, Purulent exudate, Separation of deep tissues, Isolation of bacteria and Stay as inpatient prolonged over fourteen days) wound scoring method (Table S1).

2.7.2 | Surgical variables

Surgical variables were recorded only for the primary thoracotomy. Time to complete the approach was defined as the time from the first skin incision to placement of the thoracic retractor. Time to complete the closure was defined as the time from commencement of circumcostal sutures to the time of completion of skin closure. Incision length was defined as the distance from the most proximal to the most distal ends of the skin incision. Estimated blood loss during the approach was measured to determine whether sparing or transection of muscles had a significant effect on hemorrhage. This was performed by weighing swabs used and measuring suctioned blood during the surgical approach. The use of saline to presoak swabs was not permitted to avoid overestimation of blood loss.

2.8 | Statistical analysis

Exact Wilcoxon signed-ranks tests were performed for dogs in each group to compare preoperative SI to the 3-day-postoperative SI and the 8- to 12-week-postoperative SI. Exact Mann–Whitney *U* tests were used to compare the absolute differences in SI (preoperative to 3-day postoperative and preoperative to 8- to 12-week postoperative) between the two groups. The exact Mann–Whitney *U* test was also used to compare preoperative and postoperative pain scores. A repeated-measures analysis of variance

(ANOVA) was carried out on the CBPI data to assess for differences in the pattern of change in the scores across time between the two treatment groups for both pain severity and pain interference. Sphericity (the equality of variances of the differences between treatment groups) could not be assumed, so a Greenhouse–Geisser correction was used. The assumptions required for repeated-measures ANOVA were checked, and normality of errors and homogeneity of variance were found to be satisfactory. Exact Mann–Whitney *U* tests were used to test for differences between treatment groups in the duration of surgical approach, duration of surgical closure, incision length, estimated blood loss during approach, and postoperative surgical site inflammation. Analyses were performed in SPSS Statistics v26.0 (IBM, Armonk, New York). Bootstrapped estimates of medians and their 95% CI were reported for the Wilcoxon signed-ranks tests and the Mann–Whitney *U* tests. $P < .05$ was considered significant for all tests.

3 | RESULTS

Dogs were enrolled between March 2016 and June 2019. Thirty-nine dogs met the eligibility criteria for inclusion in the study, and 11 were excluded, leaving 28 (14 in each treatment group) for data analysis. Eight dogs were excluded before surgery because of widespread metastatic disease (n = 6) or unwillingness to trot over the force plate (n = 2). Three dogs were excluded after surgery either because of euthanasia (n = 1), unrelated lameness (n = 1), or concern that physical condition may affect force plate measurements (hypertrophic osteopathy, n = 1). Complete data were obtained for 23 dogs, and five dogs were euthanized prior to the 8- to 12-week-postoperative follow-up (three dogs in the MSLT group and two dogs in the SLT group). These dogs were still included in analysis of preoperative and 3-day-postoperative data. Breeds included in the MSLT group were Labrador retriever (n = 3), crossbreeds (n = 2), and one each of Staffordshire bull terrier, lurcher, golden retriever, border collie, Parson Russell terrier, Siberian husky, greyhound, Shiba Inu, and Cavalier King Charles spaniel. In the SLT group breeds included were Labrador retriever (n = 3), greyhound (n = 2), crossbreed (n = 2), and one each of Welsh corgi, boxer, golden retriever, English springer spaniel, border collie, cairn terrier, and bullmastiff. Surgical indications were varied (Table 1). Two dogs in the SLT group and five dogs in the MSLT group underwent an additional thoracotomy, among which one underwent an additional ipsilateral thoracotomy at the 11th intercostal space 9 days later. Mean weight was 26.6 kg (SD, 11.7; range, 11.3-55), and mean age was 7.1 years (SD, 3.6; range, 0.5-13). For every dog in each group, the SI at 3 days postoperatively was lower than the preoperative value, providing evidence of ipsilateral forelimb lameness to the side of surgery. There were differences in both groups ($P < .001$). The preoperative values were not different compared with the 8- to 12-week-postoperative values for both MSLT ($P = .77$) and SLT ($P = .62$) groups, indicating resolution of postoperative lameness (Table S2, Figure 3). The absolute differences in preoperative SI and 3-day-postoperative SI were greater for dogs in the SLT group compared with those in the MSLT group ($P = .009$; median of the absolute differences in preoperative to 3-day-postoperative SI of the MSLT and SLT groups = 4.98 and 15.51, respectively), indicating 3.1-fold more severe ipsilateral forelimb lameness in the SLT group. Among the dogs that survived to the 8- to 12-week-postoperative follow-up, the absolute differences in preoperative SI and 8- to 12-week-postoperative SI were not

TABLE 1 Surgical procedures for each treatment group

Surgical procedure	Treatment group[a] MSLT, n	SLT, n
Lung lobectomy	8	6
Pericardectomy	2	4
Thoracic duct ligation and pericardectomy	3	3
Vascular ring anomaly	0	1
Removal of free thoracic foreign body due to historic stick injury	1	0

Abbreviations: MSLT, muscle-sparing lateral thoracotomy; SLT, standard lateral thoracotomy.
[a]N = 28, n = 14 per group.

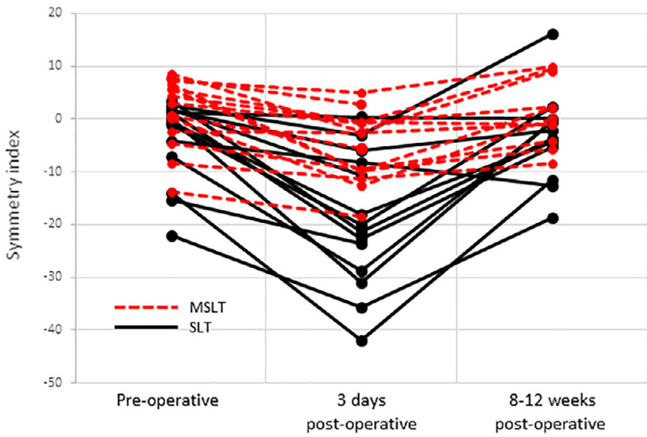

FIGURE 3 Results of force plate gait analysis. The symmetry indices for each dog are illustrated at the three time points. MSLT, muscle-sparing lateral thoracotomy; SLT, standard lateral thoracotomy

different between groups (P = .98; median of the absolute differences in preoperative SI to 8- to 12-week-postoperative SI of the MSLT and SLT groups = 0.02 and 0.65, respectively; Table S3, Figure 3). The mean pain scores were lower in the MSLT group on day 1 after surgery (P < .001; median scores in the MSLT and SLT groups = 1.0 and 2.5, respectively), but there was no difference in mean pain scores between groups on day 2 (P = .30) or day 3 (P = .56; Table S4). Regarding the CBPI scores, repeated-measures ANOVA was carried out to assess for differences in the pattern of change in the postoperative scores (7 days postdischarge, 4 weeks postoperatively, and 8-12 weeks postoperatively) across time between the two treatment groups for pain severity and pain interference. For pain severity, there was a trend for the pattern of change over time to differ between treatments ($F_{2,44}$ = 2.761, P = .096; Figure 4). There was also a strong trend for an overall difference in between-subject effects (ie, the overall level of the scores given in each group [$F_{1,22}$ = 4.124, P = .055, mean average across all three time periods postoperatively in the SLT group = 0.937, standard error = 0.147, mean average across all three time periods postoperatively in the MSLT group = 0.495, standard error 0.160]). Regarding pain interference, there was an overall change over time ($F_{2,44}$ = 37.455, P < .001); however, no difference was seen between treatment groups in the pattern of change of pain interference over time ($F_{2,44}$ = 0.467, P = .516, mean average pain interference score in both groups at 7 days postdischarge = 2.43, standard error = 0.32, mean average pain interference score in both groups at 4 weeks postoperatively = 0.27, standard error = 0.09, mean average pain interference score in both groups 8 to 12 weeks postoperatively = 0.22, standard error = 0.09). Among the surgical variables, estimated blood loss during the approach was lower in the MSLT group (P = .025), but no differences between groups were found in incision length (P = .43), duration of surgical approach (P = .59), or closure (P = .41; Table S5). No differences were found between groups for postoperative inflammation of the surgical site after 24 hours (P = > .99), 48 hours (P = .48), or 72 hours (P = .18; Table S6). There were no cases where the MSLT had to be converted to an SLT because of inability to gain adequate exposure of the thoracic cavity.

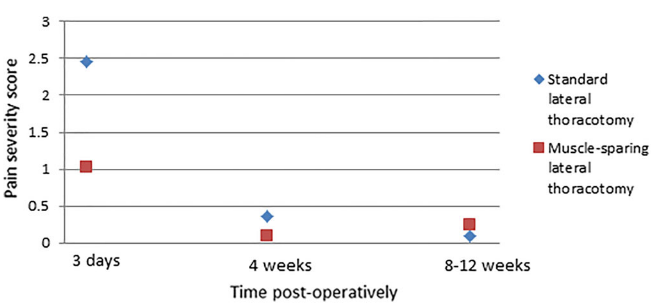

FIGURE 4 Canine Brief Pain Inventory mean pain severity scores within each group

4 | DISCUSSION

The hypothesis that MSLT would reduce immediate postoperative pain and lameness was confirmed on the basis of our results. We found that both MSLT and SLT caused postoperative ipsilateral thoracic limb lameness, but the degree of lameness was three times less when MSLT was performed. Muscle-sparing lateral thoracotomy reduced pain scores by two and a half times the day after surgery, and there was a clear trend toward overall lower pain severity scores in this group as measured by the CBPI. In addition, there was less hemorrhage with MSLT compared with SLT.

While some researchers have associated postoperative thoracotomy related pain with rib retraction and neurovascular compression by suture during circumcostal rib closure,[2,4-6] we found worsened ipsilateral thoracic limb lameness in the SLT group, which provides evidence that incision of the muscles overlying the intercostal muscles is a major contributor to pain. In particular, we propose that incisions in the latissimus dorsi and serratus ventralis are the main sources of pain because these were the muscles that could reliably be spared in all dogs in the MSLT group. However, because all dogs were lame on the ipsilateral thoracic limb to some degree postoperatively, it can be concluded that muscle transection is not the sole cause of pain. Trauma to the muscles overlying the ribs via dissection between planes and retraction may also be partially responsible as well as transection of the intercostal muscles, incision of the pleura, rib retraction, and costal closure. However because these structures are not involved in limb function, it is uncertain how their damage would cause lameness. Exclusion of intercostal nerve entrapment as a possible confounding factor would have been desirable, but we chose to perform intercostal closure using circumcostal sutures to maximize the number of dogs included in the study. Placement of transcostal sutures in dogs has been reported only in dogs weighing over 22 kg,[2] and, in the authors' experience, it can be challenging in smaller dogs and risks rib fracture because of the narrow width.

We chose to examine PVF as the primary measure of lameness because this has been found to be the most reliable measurable ground reaction force.[15,16] The use of an SI for PVF analysis was selected instead of the absolute PVF values. This is because SI eliminates interdog variations (eg, breed and body condition) because every dog is its own control, and is reported to achieve high gait analysis precision and accuracy.[15-18] Only one dog in our study had a preoperative SI of zero (ie, perfect symmetry), and the dog with the greatest asymmetry had an SI of −22.0 (22%). It is possible that the dogs with asymmetry had preclinical lameness preoperatively, but asymmetry has been reported to be a normal finding in various species, including dogs.[15,16,18,19] The dog with an SI of 22% was deemed normal at physical and orthopedic examination and had no history of prior orthopedic conditions. In addition, at the final examination, the SI was similar to that preoperatively (18.6%).

Velocity was also controlled because PVF increases with increased velocity.[20-22] We allowed dogs to trot at their habitual pace during each of the three gait analysis sessions, but ensured that the valid trials were all within 0.7 m/second of each other.

We excluded dogs <10 kg after initial trials with the gait laboratory equipment. This was because of difficulties in correctly identifying right and left paw strikes on the force plate in small dogs. The conformation of some smaller dogs, usually ones with disproportionally short legs, meant that the reflective markers weren't seen by enough of the cameras to identify them at all stages of the gait cycle.

Observer pain scores were significantly lower in the MSLT group on the day after surgery. There were no significant differences in subsequent pain scores. However, the ipsilateral forelimb lameness was detected during force plate analysis 3 days after surgery. This discrepancy is most likely explained by the subjective nature of pain scoring because the GCMPS-SF relies on observer recognition of behavioral alterations and, as such, is susceptible to bias.[23,24] We chose to score lameness using force plate analysis because of its superiority compared with visual observation of gait; it has been reported that 75% of dogs with no observable lameness failed to achieve ground reaction forces consistent with sound Labradors.[25] It is therefore probable that a significant proportion of our study population exhibited no or only mild observable signs of pain on days 2 and 3 postoperatively, and these low pain scores were indistinguishable between groups. The median pain scores in each group (MSLT, 1; SLT, 2.5) were both lower than the threshold for pain rescue, which may lead the reader to believe that neither technique causes severe pain. However, techniques should be employed to reduce pain to the lowest level possible; therefore, these low scores should not be disregarded. In addition, all dogs received robust multimodal analgesia, so high pain scores should not have been expected.

The results of the CBPI provided evidence to partially support the gait analysis and pain scoring. There was a strong trend for the overall level of pain severity to be greater in the SLT group, but there were no trends for pain interference between treatment groups. This lack of correlation may be due to the fact that, for the 7-day-postoperative scores, one-third of owners did not answer the pain interference question relating to the dog's ability to run because they were restricting their exercise. Because this question was likely to be one of the higher scoring ones, it could have resulted in an overall reduction in mean pain interference scores.

Estimated blood loss during the approach was found to be less in the MSLT group, providing evidence that transection of the latissimus dorsi, serratus ventralis, external abdominal oblique, and scalenus contributes significantly to hemorrhage on the surgical approach. However, overall, the amount of hemorrhage per dog in the SLT group was still considered minimal (0.3 mL/kg), so the results do not add substantial weight to the argument for performing MSLT rather than SLT. However, for severely compromised animals (eg, those with severe anemia or shock), the findings may be of greater importance.

We acknowledge several limitations to this study. Our study population was heterogeneous, with a wide range of breeds and bodyweights. The use of SI allowed us to normalize the data, so heterogeneity should not have affected the results. However, the differences in conformation (eg, different latissimus dorsi muscular development) may have impacted the results. Second, in each of the study groups, some of the dogs underwent an additional intercostal thoracotomy at the time of surgery. These dogs were still included in the study because the second thoracotomy level was caudal enough that retraction or transection of the latissimus dorsi was not required. It is possible that pain from the second thoracotomy could have affected the results, in particular the pain scores, although our results provided evidence of significantly decreased pain and lameness in the MSLT group despite a larger number of these dogs undergoing two thoracotomies. An additional limitation was that dogs requiring thoracocentesis or thoracostomy tube placement prior to the first gait analysis session were also included (five in each treatment group), and this too could have affected the preoperative ground reaction forces or pain score. However, all but one of these dogs had preoperative SI less than 9%, and all were within a published lameness cutoff value of 15.7%.[16] It was suspected that some of the older dogs included (three in the SLT group and two in the MSLT group), while not visibly lame, had a degree of osteoarthritis on the basis of orthopedic examination. This could have affected the results of the gait analysis, first, because these dogs may have had subclinical lameness that fluctuated in severity over the study period and, second, because the period of hospitalization and reduced exercise could have led to joint stiffness or lameness. With respect to surgical technique for MSLT, retraction of the latissimus dorsi and serratus ventralis resulted in satisfactory access to the dorsal thoracic cavity and visualization of the intrathoracic structures, and no cases required conversion to SLT. However, sometimes it was not possible to obtain adequate exposure of the ventral thoracic cavity by retraction of the external abdominal oblique and/or scalenus, and, in those cases, conservative incision of the muscles was performed as required. This was not specifically recorded for each dog because it was not always possible to determine whether or how much of the muscle was indeed transected or retracted. While this may represent a limitation, these muscles are not involved in limb movement, so, while pain scores may have been slightly affected, transection of these muscles should not have affected the force plate results. The degree of thoracic exposure and visualization of the intrathoracic structures between the two surgical techniques was not objectively evaluated in this study; this would require additional investigation. Finally, because of the duration of data acquisition, an extended group of observers was required for pain and inflammation scoring, which may have led to inconsistency in scoring across our population of dogs. However, the GCMPS-SF is deemed to produce consistent results by multiple observers.[24] In addition, it was ensured that each dog was always scored by the same individual.

In conclusion, we found MSLT to be acceptable and indeed preferable compared with SLT. Dogs that underwent MSLT exhibited less pain on the day after surgery and were less lame at 3 days postoperatively than those that underwent SLT. In addition, MSLT reduced hemorrhage during the surgical approach, had no effect on the time of approach or closure, and did not require a longer incision or result in more severe postoperative inflammation of the wound. Sparing the latissimus dorsi should therefore be considered to decrease immediate postoperative morbidity in dogs undergoing lateral thoracotomy.

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AUTHOR CONTRIBUTIONS

Nutt AE, BVM&S, MANZCVS, DECVS, MRCVS: Conception and design of the work, gait analysis and coordination of the experiment, analysis of data for statistical significance, and writing of manuscript; Knowles TG, BSc (Agric), MSc, PhD (Cantab), CStat, CBiol, CSci, FRSB, FHEA: Analysis of data for statistical significance, and manuscript preparation; Nutt NG, MEng (Hons) Civil Engineering, CEng, MICE: Gait analysis, pre-processing of force plate data using scripting prior to statistical analysis, and manuscript preparation; Murrell JC, BVSc (Hons), PhD, DECVAA, MRCVS: Design of anesthesia and pain protocol, design of post-operative pain scoring, and manuscript preparation; Carwardine D, BVSc, PhD, FHEA, MRCVS: Gait analysis, coordination of the experiment, and manuscript preparation; Meakin LB, MA, MRes, PhD, VetMB, DECVS, MRCVS: Enrollment of patients, acquisition of surgical data, and manuscript preparation; Chanoit G, DEDV, PhD, DECVS, DACVS, FHEA, MRCVS: Design of the work, acquisition of surgical data, and manuscript preparation.

CONFLICT OF INTEREST

The authors declare no conflicts of interest related to this report.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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